UNIVERSITY OF SASKATCHEWAN

College of Engineering

Department of Physics and Engineering Physics

E.P. 155.3

Electric and Magnetic Circuits I

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FINAL EXAMINATION

April 29th, 2005

2:00 PM - 5:00 PM

Indicate the E.P. 155.3 Lecture Section that you are registered in.

- ☐ Section 02 (T-Th 1:00-2:30) PAC Gym
- ☐ Section 04 (T-Th 2:30-4:00) Education Gym

STUDENT NAME: _____

STUDENT NUMBER: _____

Question 1	/ 9
Question 2	/ 8
Question 3	/ 8
Question 4	/ 8
Question 5	/ 6

Question 6	/ 6
Question 7	/ 10
Question 8	/ 6
Question 9	/ 4

TOTAL	/ 65

GENERAL INSTRUCTIONS FOR THE QUESTIONS

1) **Please place your answers in the boxes provided. Show units in all answers.**
2) Calculator allowed. One page (8½ x 11) double-sided of formulae allowed.
3) Please ensure that your name and student number are entered on every page.
4) Neatness counts. Please ensure your paper is readable. Please show your work.
5) Some questions contain special instructions. Please ensure that you read these carefully.
6) Not all questions are of the same difficulty and value. Please consider this when allocating time for the solution.
7) IF A QUESTION PROVES TO BE TOO HARD FOR YOU TO SOLVE, GO ON TO ANOTHER QUESTION! RETURN TO THE TROUBLESOME QUESTION WHEN TIME PERMITS.

Physical Constants

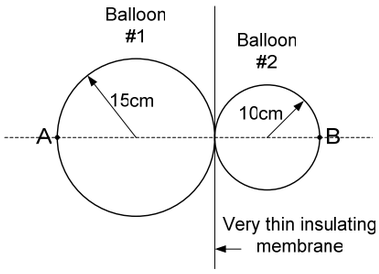
Constant	Symbol	Value	Units
Coulomb's law constant	k	9.0×10^{9}	Nm^2/C^2
Permittivity of free space	ε_0	8.854×10^{-12}	farad/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$	H/m
Relative permeability of cast iron	μ_r	1.75×10^{3}	
Breakdown voltage of Air		3	volts/μm
Breakdown voltage of Wax		10	volts/μm

Please check that your examination paper contains 16 pages TOTAL.

QUESTION #1

MARKS: 9 (2 + 2 + 2 + 1 + 2)

a) Two balloons are inflated into perfect spheres and placed as shown in the figure below. The balloons are separated by an insulator so thin that its thickness is negligible for this question. The larger balloon, denoted balloon #1, has a radius of 15 cm. The smaller balloon, denoted balloon #2, has a radius of 10 cm.



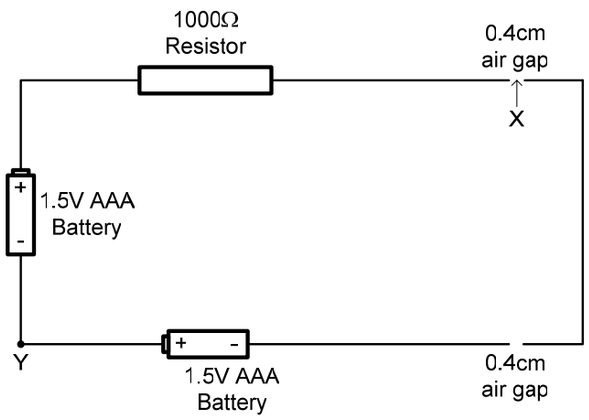
Balloon #1 has a net excess charge of $Q_1 = -0.25 \times 10^{-6}$ C evenly distributed in its rubber shell. Balloon #2 has a net excess charge of $Q_2 = +10 \times 10^{-9}$ C evenly distributed in its rubber shell.

I. What is the net force on balloon #1 due to the excess charges Q_1 and Q_2? Hint: the shell theorem can be used to model the balloons as point charges located at their centers.

II. What is the electric potential at point A with respect to point B (i.e., V_{AB})? Points A and B lie on a line that runs through the centers of the balloons.

III. What is the strength and direction of the electric field at point B?

b) The physical layout of two batteries, a resistor and some wire are shown in the figure below. It is not really a circuit because there are two places where the wires are not joined. The two air gaps are of the same length, each 0.4cm. Point X is located in the center of one of the air gaps.



I. What is V_{XY}?

II. What is the approximate strength of the electric field at point X?

USE THE NEXT PAGE AS A CALCULATION PAGE FOR THIS QUESTION.

a I) Net force on balloon #1 due to the excess charges Q_1 and Q_2? (2 marks)	**b I) Voltage V_{XY}? (1 mark)**
a II) Electric potential at point A with respect to point B (i.e., V_{AB})? (2 marks)	**b II) Approximate strength of the electric field at point X? (2 marks)**

a III) Strength and direction of the electric field at point B? (2 marks)

Strength: **Direction:**

Name: _____ **Student Number:** _____

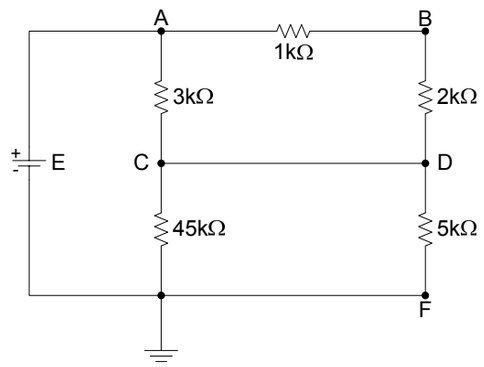
QUESTION #1 Work Sheet

Name: _____ Student Number: _____

QUESTION #2

MARKS: 8 (1 + 1 + 2 + 1 + 1 + 1 + 1)

In the circuit shown below, the voltage V_{BC} is +1.0 Volts.



Find the following:

a) The magnitude of the current through the 2kΩ resistor.
b) The magnitude of the current through the 3kΩ resistor.
c) The magnitude and direction of the current through the wire between points C and D.
d) The total resistance as seen by the battery.
e) The source voltage E.
f) The electric potential at the point D.
g) The reading on a voltmeter with total resistance of 6kΩ that is connected between points A and F.

USE THE NEXT PAGE AS A CALCULATION PAGE FOR THIS QUESTION.

a) $I_{2k\Omega}$? (1 mark)

b) $I_{3k\Omega}$? (1 mark)

c) I (between C and D) ? (2 marks)

Magnitude? **Direction? (circle one):** **← Left** **Right →**

d) Total resistance seen by battery? (1 mark)

e) Source voltage E? (1 mark)

f) Electric potential at point D? (1 mark)

g) Voltmeter reading? (1 mark)

Name: _____ **Student Number:** _____

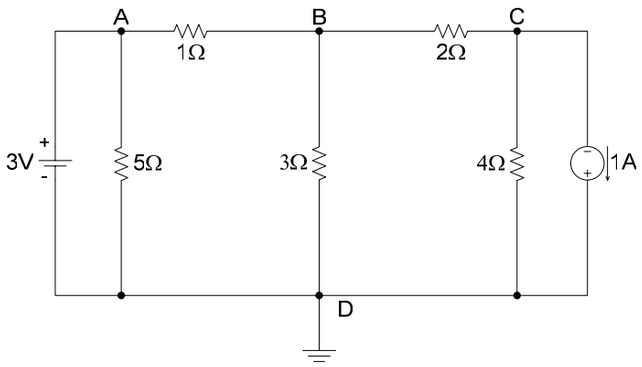
QUESTION #2 Work Sheet

Name: _____ Student Number: _____

QUESTION #3

MARKS: 8 (2 + 2 + 1 + 1 + 2)

The circuit shown below has one voltage source and one current source.



a) Find the magnitude and direction of the current $I'_{3\Omega}$ due to the 3V battery.

b) Find the magnitude and direction of the current $I''_{3\Omega}$ due to the 1A current source (you are NOT allowed to use a conversion to an equivalent battery).

c) Determine the total current through the 3Ω resistor and total power delivered to the 3Ω resistor by the two sources.

d) Show an equivalent circuit for the 1A current source and the 4Ω resistor when they are converted to a battery and a resistor.

e) What is the work required to move -0.5 coulomb of charge from point D to point A along the path D-C-B-A?

USE THE NEXT PAGE AS A CALCULATION PAGE FOR THIS QUESTION.

a) $I'_{3\Omega}$ (magnitude and direction) due to the 3V battery? (2 marks)

Magnitude?

Direction? (circle one): ↑ Up ↓ Down

b) $I''_{3\Omega}$ (magnitude and direction) due to the 1A current source? (2 marks)

Magnitude?

Direction? (circle one): ↑ Up ↓ Down

c) Total current through the 3Ω resistor and total power delivered to the 3Ω resistor by the two sources? (1 mark)

Current: Power:

d) Equivalent circuit for the 1A current source and the 4Ω resistor? (1 mark)

e) Work required? (2 marks)

Name: _____ Student Number: _____

QUESTION #3 Work Sheet

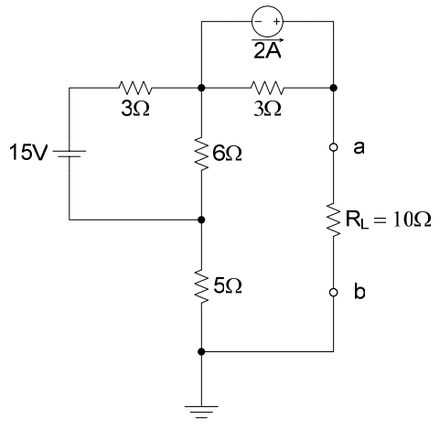
Name: _____ Student Number: _____

QUESTION #4

MARKS: 8 (4 + 2 + 1 + 1)

Consider the circuit shown below.

a) Determine the Thévenin equivalent circuit for terminals a-b. Draw your resulting circuit and indicate polarity.
b) Based upon your answer in part a), what is the Norton equivalent circuit for terminals a-b?
c) Is the value of load resistance, R_L, appropriate for maximum power transfer?
d) What is the power dissipated in the load resistor, R_L?



USE THE NEXT PAGE AS A CALCULATION PAGE FOR THIS QUESTION.

a) E_{TH}? (2 marks) **R_{TH}? (2 marks)**	**b) I_N? (1 mark)** **R_N? (1 mark)**
c) Is R_L appropriate for maximum power transfer (circle one)? (1 mark) **NO YES**	**d) Power dissipated in R_L? (1 mark)**

Name: _____ **Student Number:** _____

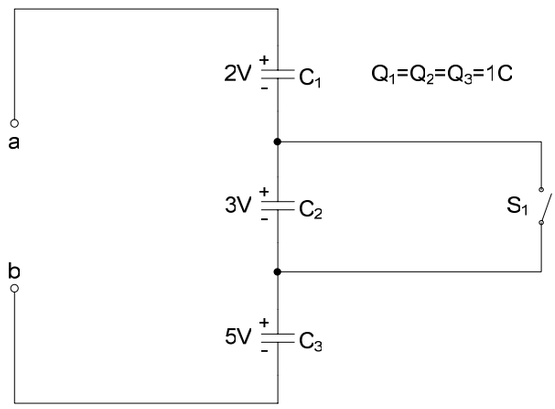
QUESTION #4 Work Sheet

Name: _____ Student Number: _____

QUESTION #5

MARKS: 6 (4 + 2)

Consider the circuit shown below. S_1 is open. The voltage across each of the capacitors is as indicated. It is known that 1 coulomb (1C) of charge is stored on the plates in each capacitor.



a) **S_1 is open**. Determine the equivalent capacitance at terminals a-b.

b) **After S_1 is closed**. Determine the charge on the plates in the capacitors C_1 and C_3.

S_1 open	**S_1 closed**
a) Equivalent capacitance? (4 marks)	**b) Charge on the plates in C_1? (1 mark)** **Charge on the plates in C_3? (1 mark)**

Name: _____ **Student Number:** _____

QUESTION #6

MARKS: 6 (2 + 2 + 2)

An air filled parallel-plate capacitor has a capacitance of 1.3pF. The separation of the plates is doubled and a wax dielectric is inserted between them. The new value of the capacitance is measured to be 2.6pF.

a) What is the dielectric constant (i.e., relative permittivity) of the wax?
b) If the area of each plate is $1 \times 10^{-4} m^2$, at what voltage will the 2.6pF capacitor with the wax dielectric breakdown?
c) The wax dielectric is removed from the parallel plate capacitor and the plates are kept the same distance apart. A voltage of 1000 volts is placed across the capacitor. Will the air between the plates breakdown?

a) Dielectric constant of wax? (2 marks)

b) Voltage at which 2.6pF capacitor breaks down (with wax dielectric)? (2 marks)

c) Does capacitor break down with 100V across it (with air)? (2 marks)

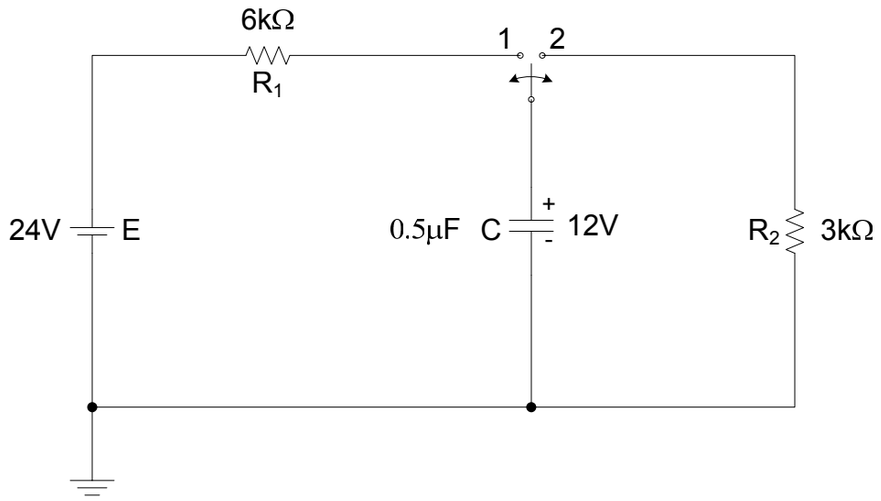
NO YES

Name: _____ **Student Number:** _____

QUESTION #7

MARKS: 10 (3 + 4 + 3)

Consider the circuit shown below. The switch is initially open (i.e., placed in the center position) and the capacitor initially has a voltage across its terminals of 12V with polarity as shown.



a) The switch is moved to position 1 at time t=0 and kept in that position for 6 ms.

   I. What is the value of the voltage across the terminals of the capacitor, v_c, at time 6ms?

b) At time 6ms, the switch is moved from position 1 to position 2. At time 9ms the switch is returned to its initial position (i.e., placed in the center position).

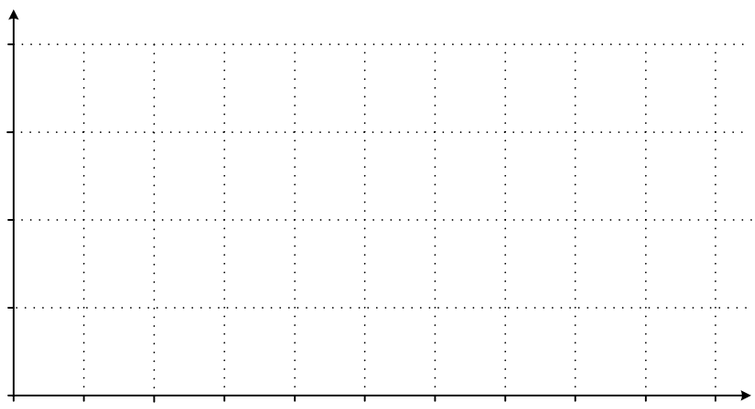
   I. What is the value of the voltage across the terminals of the capacitor, v_c, at time 9ms?

   II. What is the value of the energy stored by the capacitor at time 9ms?

c) Draw a sketch (using the template given below) of the capacitor voltage as a function of time. While the sketch does not have to be to scale it should be accurately drawn. Indicate all important times and capacitor voltage values.

USE THE NEXT PAGE AS A CALCULATION PAGE FOR THIS QUESTION.

a) Value of capacitor voltage, v_c, at time 6ms? (3 marks)	**b I) Value of the capacitor voltage, v_c, at time 9ms? (2 marks)** **b II) Energy stored by the capacitor at time 9ms? (2 marks)**



Name: _____ **Student Number:** _____

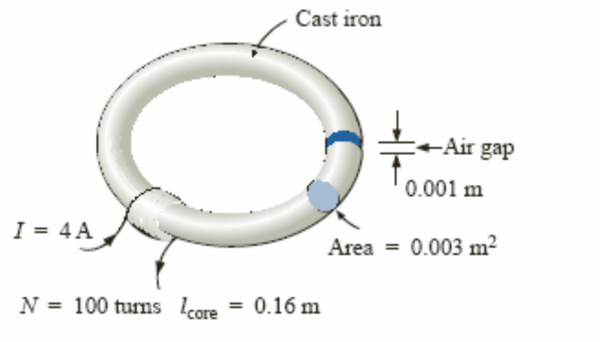
QUESTION #7 Work Sheet

Name: _____ Student Number: _____

QUESTION #8

MARKS: 6 (1 + 5)

Consider the toroid (with air gap) shown below. The cast iron portion of the toroid has an average length of 0.16m and a circular cross-sectional area of $3x10^{-3}m^2$.



a) What is the direction of the flux, Φ, due to the current I?

b) For the indicated current, I = 4A, what is the total flux created in the magnetic circuit?

a) Flux direction due to I (circle one)? (1 marks) ↻ CLOCKWISE COUNTER-CLOCKWISE ↺	b) Value of total flux, Φ, due to I=4A? (5 marks)

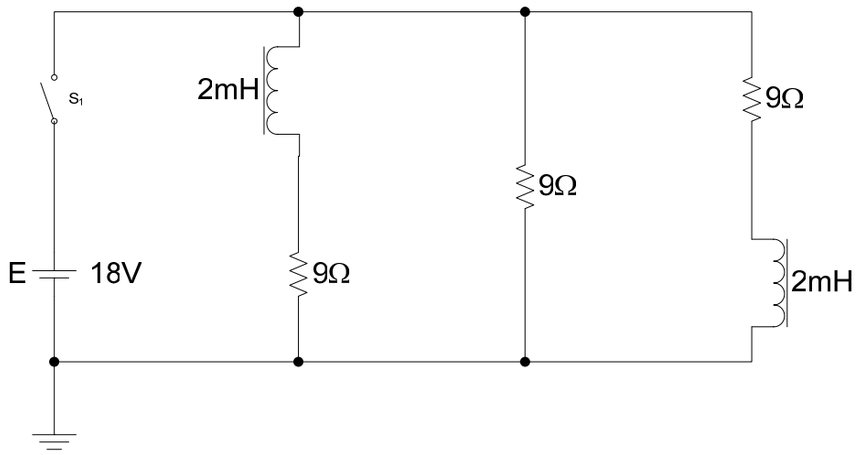
Name: _____ **Student Number:** _____

QUESTION #9

MARKS: 4 (2 + 2)

This question was Problem 3) on Assignment #11. It is duplicated here as given in the Assignment.

This question does **not** involve transient response. The circuit shown below consists of 3 resistors all of value 9Ω and two 2mH inductors connected as shown:



a) What is the current in the circuit immediately after the switch is closed (i.e., at $t=0_+$)?
b) What is the current in the circuit a long period of time after the switch is closed?

a) Current at $t=0_+$? (2 marks)	b) Current after a long time? (2 marks)

Name: _____ **Student Number:** _____

Extra Work Sheet

Name: _____ Student Number: _____